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THE CHANGES SHOWN ARE REFLECTED IN THE SUBSTITUTE SPECIFICATION SUBMITTED
HEREWITH.

_____ Title of Invention

Lawnmower Rotary Cutting Apparatus and Grass Guide

[0001] Original application submitted by Daniel Charles Heinz (joint inventor) of 4303 Florio Drive, Perry Hall, MD 21128, Citizen of the United States of America, and Daniel John Heinz (joint inventor) of 659 Shore Drive, Joppa, MD 21085, Citizen of the United States of America.

_____ Cross Reference to [r]Related Application

[0002] This nonprovisional utility patent application was filed within one year of and claims a domestic priority date of November 18, 2003 based on U.S. Provisional Patent Application 10/715,192, filed November 18, 2003.

~~U.S. Patent 4,031,696, June 28, 1977, "Blade configuration for cordless lawnmower", Fleigle, Donald Earl.~~

~~U.S. Patent 4,052,789, Oct. 11, 1977, "Rotary cutting assembly", Ballas, George Charles Sr.~~

~~U.S. Patent 4,064,680, December 27, 1977, "Cordless twin blade lawnmower construction", Fleigle, Donald Earl.~~

~~U.S. Patent 4,987,729, Jan. 29 1991, "Solar powered mower", Paytas, Anthony R.~~

~~U.S. Patent 5,007,234, Apr. 16, 1991, "Automatic self guiding lawn mower and mowing method", Shurman etc.~~

~~U.S. Patent 5,261,217, Nov. 16, 1993, "Cutting Head for lawnmower", Allen, Frank R.~~

~~U.S. Patent 5,572,856, Nov. 12, 1996, "Remotely controlled lawn mower", Ku, Chingyu J.~~

~~U.S. Patent 5,761,892, June 9, 1998, "Rotary Mower", Quiroga, Osvaldo R.~~

~~U.S. Patent 6,427,429, Aug. 6, 2002, "Multiple String Mower", Brabenec, William.~~

Statement Regarding Federally Sponsored Research

[0003] No federal funds were used to sponsor any of the research related to the development of the invention described in this patent application.

Names of Parties to a Joint Research Agreement

[0004] The development of the invention described in this patent application is not the product of any joint research and development agreement.

Background of the Invention

[0005] Field of the Invention: Most conventional lawnmowers cut the lawn using one or more large metal blades rotating in a plane of rotation that is substantially parallel to the land surface beneath the grass being mowed. Additionally, most conventional lawnmowers have some type of blade height adjustment. Blade height adjustments are typically achieved by raising or lowering the lawnmower chassis relative to the land surface, and may require a fair amount of time and additional tools. These adjustments can be used to reduce the power required to cut the lawn by raising the blade. However, once a blade height is selected the height and thickness of the lawn and the velocity in which the mower is moved through the lawn determine the blade's cutting area and commensurate amount of power required by the lawnmower. To accommodate the wide variety of grass heights and densities while providing for adequate speed of forward movement to satisfy the user, most lawnmowers are powered by internal combustion engines of significant horsepower. Moreover, mowers utilizing a plurality of large blades, such as riding mowers or large-swath mowers towed by a tractor, typically require gearing mechanisms to achieve increased speeds, and may become bogged down and stall in high, dense grass at high speeds.

[0006] Electric motors of equal horsepower are also used to power conventional lawnmowers, but finding an efficacious power source to drive such electric motors has proven challenging. For instance, the batteries required to supply enough power for an adequate mowing time are typically prohibitive in size, weight and expense, while the typical home (20-amperes) circuit restricts power supplied by a power cord. Furthermore, a cord also restricts ease of movement of the lawnmower, as well as the distance the mower can travel from the outlet into which the cord is plugged.

[0007] The combination of one or more large blades and a powerful internal combustion engine or electric motor also presents a safety hazard, since the blade is capable of cutting with significant force. A further drawback is the relatively large size and weight of lawnmowers utilizing a powerful internal combustion engine or large electric motor, which reduces the ease of lawnmower operation and storage. With respect to lawnmowers powered by internal combustion engines, a further drawback is that the user typically incurs the cost of purchasing oil and gasoline or other flammable fuel and stores it at his or her home in volumes adequate to fuel the mower for a number of uses, creating a potential fire hazard at the home. Internal combustion engines also produce carbon dioxide emissions which may have a negative impact on air quality and the environment. Finally, when conventional lawnmower blades become periodically dulled and in need of replacement, the blade replacement process may be quite cumbersome to the average user, requiring substantial time and additional tools.

~~The present invention relates to a rotary cutting apparatus and grass guide used for mowing lawns. More particularly, it relates to a rotary cutting apparatus for mowing lawns using a plurality of small blades with their plane of rotation rotated between 1^0 and 90^0 from the horizontal plane of rotation. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide results in a more efficient cutting design. Additionally, the utilization of a plurality of small blades results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional~~

~~lawnmower blade. Consequently, a lawnmower utilizing this rotary cutting apparatus and grass guide will have a smaller, quieter, lighter and less powerful motor or motors. This results in a lawnmower, which is smaller, quieter, lighter and easier to operate and store than a conventional lawnmower. This design improves the operating safety by using a plurality of small blades operating with significantly less power than a conventional lawnmower. These improvements in safety, quietness, lightness and smallness would benefit both user-operated lawnmowers and self-guiding lawnmowers.~~

Background of the Invention

~~Most present day lawnmowers cut the lawn using one large blade rotating in a substantially horizontal plane of rotation. Additionally, most lawnmowers have some type of blade height adjustment. This adjustment can be used to reduce the power required to cut the lawn by raising the blade. However, once a blade height is selected the height and thickness of the lawn and the velocity in which the mower is moved through the lawn determine the blade's cutting area and amount of power required by the lawnmower. To accommodate the wide mixture of grass heights and thicknesses while providing for adequate speed of forward movement to satisfy the user, most lawnmowers have internal combustion engines of significant horsepower. Electric motors of equal horsepower are used, but an adequate power source to drive the electric motor becomes the problem. For instance, the batteries required to supply enough power for an adequate mowing time are prohibitive in size, weight and expense. Similarly, the typical home 20 amp circuit restricts power supplied by a power cord. A power cord also restricts ease of movement.~~

~~The combination of a single large blade and a powerful internal combustion engine or electric motor also presents a safety hazard since the blade is capable of cutting with significant force. A further drawback is the relatively large size and weight of lawnmowers utilizing a powerful internal combustion engine or large electric motor, which reduces the ease of lawnmower operation and storage.~~

~~In U.S. Pat. No. 5,761,892, Quiroga discloses a rotary blade for a rotary lawnmower that provides an equivalent cut with substantial reduction in necessary driving power. In the present invention different techniques are used to reduce the necessary driving power.~~

[0008] Description of the Related Art: U.S. Patent No. 3,070,938 ("the '938 patent) discloses a lawnmower comprising a plurality of individual blade units that operate together as a unit in order to cut a wider swath than mowers existing in the art at the time of the invention embodied therein. The apparatus disclosed in the '938 patent was designed for attachment to a tractor or other powered vehicle and was designed to be raised and lowered in order to follow the topography of the land surface being mowed. While the planes of rotation of the plurality of blades described in the '938 patent are not at all times perfectly parallel to the land being mowed when the mower is in use, they do remain substantially parallel to the land surface, and the cutting area of each blade of the invention embodied in the '938 patent is thus greater than that of the blades used in the present invention. The reduction in cutting area is a significant feature of the present invention inasmuch as the amount of power required is reduced as compared to the plurality of blades used in the invention disclosed in the '938 patent. This enables the use of alternative power sources such as batteries in the present invention to power the cutting blades while an internal combustion engine powering a separate vehicle is required in order to enable the invention of the '938 patent.

[0009] U.S. Patent No. 5,761,892 (the '892 patent) discloses a rotary blade for a rotary lawnmower that provides an equivalent cut to the invention of the '938 patent with a reduction in necessary driving power. The reduction of power described in the invention of the '892 patent is achieved by affixing a plurality of individual cutting elements to a single support arm rotating about a single rotary drive shaft, each cutting element of sufficient length and projecting downward at a suitable angle such that the cutting elements cut the grass as the support arm rotates at a height above the grass. The present invention differs from that embodied in the '892 patent because each of the

plurality of blades has its own drive shaft and the drive shafts are situated at an angle tilted longitudinally between 1 and 90 degrees from vertical. Moreover, each drive shaft of the present invention may be powered by an individual motor that uses only the power necessary to power the blade affixed thereto to cut the grass in its cutting path, thereby increasing the overall efficiency of the apparatus as a whole by requiring only the energy actually necessary to cut the grass in the path of each discrete member of the plurality of blades.

Brief Summary of Invention

~~This invention discloses both a rotary cutting apparatus, which uses a plurality of small blades with their plane of rotation rotated between 1° and 90° from the horizontal plane of rotation and a grass guide. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. This is accomplished by the grass guide bending the incoming uncut grass such that the uncut grass is only cut when the blades are in the lower portion of their plane of rotation. Therefore, the maximum amount of power required is reduced by this design. This is in contrast to a conventional lawnmower in which the power requirements are determined mostly by the velocity in which a mower is moved through the lawn. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage comes from the significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of small blades from that of a single large blade. By limiting the amount of energy required, the horsepower required by a lawnmower using the disclosed rotary cutting apparatus and grass guide is significantly reduced from that of a conventional lawnmower. This reduction of required power allows for a smaller, lighter and less powerful motor or motors. The preferred power source for portability would be a rechargeable battery or combination of solar panels and rechargeable battery, but a corded source can be used. The power source would then provide power to a plurality of electric motors. However, a single electric motor or a conventional internal combustion engine~~

~~driving a plurality of small blades can be substituted. New, alternative power sources may also be substituted. For instance, in a few years fuel cells may become the preferred power source.~~

~~Use of an electric motor or motors would result in additional power savings since each motor would independently draw additional current only as its load increased. The reduced weight and distribution of motor volume resulting from the use of a plurality of small motors is a further advantage. Since the cutting speed of a rotary blade is a function of both the rotations per minute (RPM) and the distance from the axis of rotation, the RPM of a plurality of small blades must be increased to be similar to the cutting speed of a single large blade. This increase in RPM has the advantage of providing greater cutting frequency. Through the use of a plurality of small high RPM motors this increase in RPM is easily obtained. However, increasing the RPM of a plurality of small blades using a single electric motor or a conventional internal combustion engine may require additional gearing mechanisms. Using a plurality of small electric motors has the additional advantage that each motor can be connected directly to the blade's driveshaft and no separate mechanical drive mechanism would be required as with a single motor system.~~

~~The use of a smaller lighter motor or motors results in a smaller, quieter, lighter lawnmower, which is easier to operate and store. Another advantage of this design is that the use of a plurality of small blades operating with significantly less power than a conventional lawnmower, improves operating safety. These improvements in safety, lightness and smallness would benefit both user-operated lawnmowers and self-guiding lawnmowers. Since the total mass and volume of the plurality of small blades will be significantly less than one large blade, new blade designs and different and possibly more expensive construction materials can be used. Alternatively, a string-like or wire cutting members can be substituted for the blades. An environmental advantage of using the preferred power source of a rechargeable battery or combination of solar panels and rechargeable battery is that the mower would produce zero emissions and would not require any gas or oil. Other~~

~~features and advantages of the present invention will become apparent in the following detailed description of the preferred embodiment.~~

[0010] The present invention embodies a lawnmower consisting essentially of a rotary cutting apparatus and grass guide. In a conventional mower, the blade's drive shaft is arranged such that it remains substantially perpendicular to the blade and horizontal plane of the mower. Therefore, the blade rotates in a substantially horizontal plane. Our invention is novel and unique because the blade's drive shafts are tilted between 1 and 90 degrees in the longitudinal direction from vertical. Therefore, the blades in our invention rotate in a plane tilted longitudinally at least 1 degree from horizontal. Many present day push and self-propelled lawnmowers have about a 22 inch width which allows the horizontal plane of the mower to remain substantially parallel to ground plane. The horizontal plane of the present invention would also remain substantially parallel to ground plane. While additional blades could easily be added to make our design wider than the typical 22 inch cutting width, a wider design would be limited to a width that allowed the horizontal plane of the mower to remain substantially parallel to ground plane.

[0011] More particularly, the rotary cutting apparatus comprises a plurality of small blades affixed to the end of individual drive shafts, with their planes of rotation substantially perpendicular to their respective drive shafts and to the grass guide. The grass guide is situated forward with respect to the plurality of blades, projecting downward at a height suitable for bending the grass in the path of the plurality of blades and restricting the motion of the grass for easier cutting. The rotation of the tilted small blades working in conjunction with the grass guide results in a more efficient cutting design by virtue of a reduction in the cutting area of each blade. This is accomplished by the grass guide bending the incoming uncut grass such that the uncut grass is only cut when the tilted blades are in the lower portion of their planes of rotation, reducing the power required by each blade to cut the grass in contrast to a conventional lawnmower, the power requirements of which are determined

mostly by the velocity at which a mower is moved through the lawn. Additionally, the movement-constraining function of the grass guide makes it easier for the plurality of blades to cut the grass.

[0012] A purpose of the plurality of small blades is a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades relative to that of a conventional lawnmower blade. Also by virtue of the large reduction in mass of the plurality of blades, as well as a reduction in the mass of the required power source relative to a conventional lawnmower (e.g., a plurality of small electric motors instead of an internal combustion engine), the lawnmower embodied herein is smaller, quieter, lighter and easier to operate and store than a conventional lawnmower. Moreover, the plurality of electric motors utilized in the preferred embodiment of this invention would produce no carbon dioxide emissions, conferring upon it an environmental advantage over conventional lawnmowers.

[0013] Another purpose of this novel lawnmower is to improve operating safety over that of traditional mowers by using a plurality of small blades operating with significantly less power than a conventional lawnmower. At least one published study indicates that some 80,000 Americans visited emergency rooms in 2004 as a result of lawnmower injuries, and that such injuries have been on the rise.

Brief Description of the Several Views of the Drawings

~~The present invention and its advantages will become more fully understood by way of the following description and drawings. The drawings are for illustration only, and thus are not limitative of the present invention.~~

[0014]__FIG. 1 is a side view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention.

[0015]__FIG. 2A is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity v_1 and rotating at RPM_1 for a single blade of the preferred embodiment of the present invention.

[0016]__FIG. 2B is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_2 and rotating at RPM_2 for a single blade of the preferred embodiment of the present invention.

[0017]__FIG. 3A is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_1 and rotating at RPM_1 for the blade of a conventional lawnmower.

[0018]__FIG. 3B is a top view of the blade's cutting area in black as a lawnmower is moved forward at a velocity ν_2 and rotating at RPM_2 for the blade of a conventional lawnmower.

[0019]__FIG. 4 is a front view of a lawnmower utilizing the rotary cutting apparatus and grass guide in accordance with the preferred embodiment of the present invention.

Detailed Description of the Invention

[0020] The present invention is that of a rotary cutting apparatus that comprises a plurality of small cutting blades, each cutting blade rotating about the end of a drive shaft driven by a power means, and a grass guide that constrains the movement of the individual grass blades such that the grass blades are cut by the outermost areas of the radii of the cutting blades (FIG. 1). The drive shafts may be collectively powered by a single motor, or, more preferably, each drive shaft may be powered by an individual motor that utilizes only the minimum power necessary to cut the blades of grass within the cutting area of the cutting blade attached to the drive shaft. An individual motor or a plurality of motors used to power the drive shafts and cutting blades may draw power from any source, including but not limited to an internal combustion engine, a hybrid power source powered by both internal combustion and electricity, an electrical extension cord plugged into an electrical outlet, a fuel cell, a battery or batteries, or a battery or batteries combined with a solar source, or a solar source alone.

[0021] FIG. 1 depicts the side view of an embodiment of the rotary cutting apparatus, and serves to illustrate the benefits and versatility to be derived from the design of the invention. Each cutting

blade (1) of the apparatus is mounted to the end of an individual drive shaft (7), the rotation of which is powered by a power means (2), most preferably consisting of a small electric motor powered by one or more low-voltage batteries. FIG. 1 further depicts a side view of the grass guide (6) as a rectangle projecting downward substantially parallel to the drive shafts and continuous with a semicircular extension positioned above the assembly of the power means (2), shafts (7) and cutting blades (1). The outer housing (5) and grass guide (6) may serve as the chassis of the apparatus as well, providing a mounting surface for the power means (2) and wheels (3). FIG. 1 further illustrates the adjustability of the grass guide at the high point of the apparatus, shown by a curved double-sided arrow beneath the semicircular extension of the grass guide (6). The angular range of 1 to 90 degrees from vertical (designated as 0 degrees) is shown to designate the limits of the adjustment, with two curved, double-sided arrows between either 1 or 90 degrees from vertical and the current position of the shaft in the drawing (about 45 degrees). In a preferred embodiment of the invention, the grass guide adjustment is positioned at a high point for ease of access by the user. FIG. 1 further depicts wheels (3), a handle (4) and an outer housing (5).

[0022] The rotary cutting apparatus depicted in FIG. 1 has its drive shafts (7) situated at an angle adjustably tilted between 1 and 90 degrees in the longitudinal direction from vertical. The cutting blades are arranged substantially perpendicular to their respective drive shafts. The angular adjustment capability allows the cutting area of the blades to be controlled. As the angle is increased the cutting area becomes smaller.

[0023] The grass guide (6) in FIG. 1 is shown bending the incoming grass and holding it in a rigid position such that the portion of the blade in the lower portion of the plane of rotation contacts the grass, but other portions of the blade do not. FIG. 2A illustrates the cutting area (8) of a single blade at a forward velocity $\underline{\nu_1}$, rotating at RPM_1 for the preferred embodiment of the present invention. FIG. 2B shows the blade's cutting area (9) as the apparatus is moved forward at a velocity $\underline{\nu_2}$.

rotating at RPM_2 , for a single blade of the preferred embodiment of the present invention. In contrast to FIG. 2A, FIG. 3A shows the cutting area (10) of the blade of a conventional lawnmower as it is moved forward at velocity v_1 , rotating at RPM_1 . FIG. 3B further shows the blade's cutting area (11) as the conventional lawnmower is moved forward at velocity v_2 , rotating at RPM_2 .

[0024] RPM_2 is set to have a smaller value than RPM_1 and is used to indicate times when the RPM of the blade is reduced due to increased loading as the mower encounters thicker and taller grass. Forward velocity v_2 is set to have a larger value than v_1 and is used to show the effect of greater forward velocity. FIGs. 2A and 2B serve to illustrate one of the benefits of the present invention. The grass guide and the angle of the blade from the plane of the cutting surface reduce the blade's cutting area. This means that in areas where the grass becomes too thick and tall or when the forward velocity becomes too great some portions of the grass will remain uncut. In other words, this design limits the blade's cutting area. Consequently, the maximum amount of power required is limited by this design. This is in contrast to a conventional lawnmower in which the blades cutting area is not limited, as shown in FIGs. 3A and 3B. With a conventional lawnmower, in areas where the grass becomes too thick and tall or when the forward velocity becomes too great the mower will stall. In the present invention, the combination of reducing the blade's cutting area and constraining the movement of the grass with the grass guide results in a more efficient cutting design than that of a conventional mower.

[0025] FIG. 4 illustrates a plurality of cutting blades (1), a power means consisting of a plurality of small motors (2), wheels (3), a handle (4), an outer housing (5), a grass guide (6), and a plurality of drive shafts (7) driving the cutting blades (1). This invention uses small blades whose outer radii overlap the cutting region of the grass bent and constrained by the grass guide. The plurality of blades provides for an adequate cutting width comparable to that of a conventional manual

lawnmower. The rotational kinetic energy of each blade is its ability to do work because of its motion and is usually expressed as Equation 1:

$$\underline{K = \frac{1}{2} I \omega^2,}$$

where I is the moment of inertia of the blade and ω is its angular velocity. For a rectangular blade with its axis through the center, I , the moment of inertia is expressed as Equation 2:

$$\underline{I = \frac{m}{12} (l^2 + w^2 + h^2),}$$

where l is the length, w is the width, h is the height or thickness and m is the mass of the blade. The mass of the blade may be obtained by multiplying the density of the blade by the blade volume. The total rotational kinetic energy required by a plurality of small blades is the sum of the rotational kinetic energies required for each small blade. Since the cutting speed of a rotary blade is a function of both the angular velocity and the distance from the axis of rotation, the angular velocity of the plurality of small blades must be increased to be similar to the cutting speed of a single large blade. This increase in angular velocity has the additional advantage of providing greater cutting frequency. By using small, high RPM electric motors, one can easily increase the angular velocity of a plurality of small blades. For the present invention, the angular velocity will be increased, while the largest blade dimension, length, will be decreased relative to a conventional lawnmower. Even though the product of the two squared terms l and ω in Equation 1 will be approximately equal for a conventional mower and the present invention, a large savings in rotational kinetic energy of the present invention will come from a significant decrease of mass, m , in Equation 2.

[0026] Increasing the angular velocity of a plurality of small blades using a single electric motor or a conventional internal combustion engine, however, may require a gearing mechanism. Using a plurality of small electric motors has the additional advantage that each motor can be connected directly to the blade's driveshaft and no separate mechanical drive mechanism would be required as

with a single motor system. Use of an electric motor or motors results in additional power savings since each motor would independently draw additional current only as its load increased. The reduced weight and size resulting from the use of a plurality of small motors is a further advantage of this design. One of the greatest differences between the present invention and a conventional mower is the mass of the blades. By significantly decreasing the mass m in Equation 2 through use of a plurality of small blades, the rotational kinetic energy of the disclosed invention is significantly reduced from that of a conventional mower. An experimental apparatus has been built which demonstrates this significant reduction in required rotational kinetic energy.

[0027] The blades, drive shafts, and power means of the present invention are affixed to a chassis, most preferably constructed from durable but lightweight metal or plastic, with a means affixed to said chassis that allows said chassis to move about the ground laterally and longitudinally to facilitate the ability of the blades to cut the grass, most likely wheels (FIGs. 1 and 4). As with a conventional lawnmower a blade height adjustment will be present. A handle may be affixed to the lawnmower in order that a person may be able to more easily push or pull the lawnmower laterally or longitudinally about a land surface in order to cut the grass growing thereon (FIGs. 1 and 4). Alternatively, the apparatus may be robotically propelled about the land surface on which the grass to be cut grows in order to cut the grass, eliminating the need for a handle for manual propulsion.

[0028] The use of a smaller, lighter motor or motors relative to those most typical of conventional lawnmowers results in a smaller, quieter, lighter lawnmower, which is easier to operate and store. Another advantage of this design is that the use of a plurality of small blades, operating with significantly less power than a conventional lawnmower, improves operating safety. These improvements in safety, lightness and smallness would benefit both user-operated lawnmowers and self-guiding, robotically propelled lawnmowers. Since the total mass and volume of the plurality of small blades will be significantly less than one large blade, new blade designs and different and possibly less expensive construction materials can be used. New small blade designs can further

reduce the power requirements. For instance, the blade can be designed aerodynamically to have very little air resistance, thereby further reducing the required rotational kinetic energy. Like a conventional mower the blades can be made from metal, typically hardened steel. However, like an electric or gas trimmer the blades could be made from plastic or metal or some combination of plastic and metal. They could be as simple as a nylon plastic line or more complex as a nylon plastic mold with serrated stainless steel inserts. An environmental advantage of using the preferred power source of a rechargeable battery or combination of solar panels and rechargeable battery is that the mower would not produce carbon dioxide emissions and would not require any gas or oil. Since both the blades and motors are small and inexpensive they could be designed for easy replacement in the event of failure or damage.

~~The present invention relates to a lawnmower rotary cutting apparatus using a plurality of small blades with their plane of rotation rotated between 1^0 and 90^0 from the horizontal plane of rotation. FIG. 1 illustrates a blade 1 rotated from the horizontal plane of rotation. This figure shows a small electric motor 2, wheels 3, handle 4 and outer housing 5. The incoming uncut grass is bent by the grass guide 6 such that the uncut grass is only cut when the blades are in the lower portion of their plane of rotation. FIG. 2A illustrates the cutting area 7 of a single blade at a forward velocity v_1 and rotating at RPM_1 for the preferred embodiment of the present invention. FIG. 2B shows the blade's cutting area 8 as a lawnmower is moved forward at a velocity v_2 and rotating at RPM_2 for a single blade of the preferred embodiment of the present invention. FIG. 3A shows the blade's cutting area 9 as a conventional lawnmower is moved forward at velocities v_1 and rotating at RPM_1 . FIG. 3B shows the blade's cutting area 10 as a conventional lawnmower is moved forward at velocities v_2 and rotating at RPM_2 . RPM_2 is set to have a smaller value than RPM_1 and is used to indicate times when the RPM of the blade is reduced due to increase loading from the grass becoming thicker and taller. Forward velocity v_2 is set to have a larger value than v_1 and is used to show the effect of~~

greater forward velocity. FIGS 2A and 2B illustrate that the grass guide and the angle of the blade from the horizontal plane of rotation reduce the blade's cutting area. This means that in areas where the grass becomes too thick and tall or when the forward velocity becomes too great some portions of the grass will remain uncut. In other words, this design limits the blade's cutting area; consequently, the maximum amount of power required is limited by this design. This is in contrast to a conventional lawnmower in which the blades cutting area is not limited as shown in FIGS 3A and 3B. With a conventional mower, in areas where the grass becomes too thick and tall or when the forward velocity becomes too great the mower will stall.

In addition, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. This combination of reducing the blade's cutting area and constraining the movement of the grass results in a more efficient cutting design than that of a conventional mower.

FIG. 4 illustrates a plurality of small blades 1, plurality of small motors 2, wheels 3, handle 4, outer housing 5 and grass guide 6. This invention uses small blades located at the cutting region of the bent and constrained grass. The plurality of blades provides for an adequate cutting width. The rotational kinetic energy of a blade is its ability to do work because of its motion and is usually expressed by the equation

$$\frac{1}{2} I \omega^2, \quad (1)$$

where I is the moment of inertia of the blade and ω is the angular velocity. For a rectangular blade with its axis through the center,

$$I = \frac{m}{12}(l^2 + w^2 + h^2), \quad (2)$$

where l is the length, w is the width, h is the height or thickness and m is the mass of the blade. The mass of the blade is obtained by multiplying the density of the blade by the blade volume. The total rotational kinetic energy required by a plurality of small blades is the sum of the rotational kinetic energy required for each small blade. Since the cutting speed of a rotary blade is a function of both the angular velocity and the distance from the axis of rotation, the angular velocity of the plurality of small blades must be increased to be similar to the cutting speed of a single large blade. This increase in angular velocity has the additional advantage of providing greater cutting frequency. Using small high RPM electric motors the angular velocity of a plurality of small blades can be easily increased; however, increasing the angular velocity of a plurality of small blades using a single electric motor or a conventional internal combustion engine may require a gearing mechanism. Using a plurality of small electric motors has the additional advantage that each motor can be connected directly to the blade's driveshaft and no separate mechanical drive mechanism would be required as with a single motor system. Use of an electric motor or motors results in additional power savings since each motor would independently draw additional current only as its load increased. The reduced weight and distribution of volume resulting from the use of a plurality of small motors is a further advantage.

For the disclosed invention the angular velocity ω , will be increased, while the length of the blades will be decreased from that of a conventional lawnmower. Consequently, these two squared terms in Equations (1) and (2) will approximately offset each other. The largest difference between this design and a conventional mower is the mass of the blades. By significantly decreasing the mass

~~by use of the plurality of small blades the rotational kinetic energy of the disclosed invention is significantly reduced from that of a conventional mower. An experimental apparatus was built which demonstrated this significant reduction in required rotational kinetic energy.~~

~~New small blade designs can further reduce the power requirements. For instance, the blade can be designed aerodynamically to have very little air resistance. Since the total mass and volume of the plurality of small blades will be significantly less than one large blade, different and possibly more expensive construction materials can be used. Alternatively, a string-like or wire cutting member can be substituted.~~

~~An additional advantage of this design is that the use of a plurality of small blades operating with significantly less power than a conventional lawnmower improves operating safety. Another advantage is that the use of a smaller lighter motor or motors results in a smaller, quieter and lighter lawnmower, which is easier to operate and store. An environmental advantage of using the preferred power source of a rechargeable battery or combination of solar panels and rechargeable battery is that the mower would produce zero emissions and would not require any gas or oil. These improvements in safety, lightness, quietness and smallness would benefit both user-operated lawnmowers and self-guiding lawnmowers.~~

Claims

Claim 1 (canceled): A rotary cutting apparatus for mowing lawns using a plurality of small blades with their plane of rotation rotated between 1 and 90 degrees from the horizontal plane of rotation.

Claim 2 (canceled): A grass guide, working in conjunction with the plurality of small blades in claim 1, which bends and constrains movement of the incoming grass, thereby making it easier to cut the grass.

Claim 3 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation adjustably rotated among or between some or all degrees between 1 and 90 and the grass guide of claim 2, wherein a plurality of small electric motors are used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 4 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation fixed at a single degree between 1 and 90 and the grass guide of claim 2, wherein a plurality of small electric motors are used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a

significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 5 (canceled): A lawnmower as set forth in claim 3 or 4, will be safer due to the use of a plurality of small blades and plurality of small electric motors.

Claim 6 (canceled): A lawnmower as set forth in claim 3 or 4, will be smaller due to the use of a plurality of small blades and plurality of small electric motors.

Claim 7 (canceled): A lawnmower as set forth in claim 3 or 4, will be lighter due to the use of a plurality of small blades and plurality of small electric motors.

Claim 8 (canceled): A smaller and lighter mower as set forth in claims 6 and 7 respectively, will be easier to operate.

Claim 9 (canceled): A smaller and lighter mower as set forth in claims 6 and 7 respectively, will be easier to store.

Claim 10 (canceled): A lawnmower as set forth in claim 3 or 4, will be quieter due to the use of a plurality of small electric motors.

Claim 11 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation adjustably rotated among or between some or all degrees between 1 and 90 and the grass guide of claim 2, wherein a single electric motor is used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in

conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 12 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation fixed at a single degree between 1 and 90 and the grass guide of claim 2, wherein a single electric motor is used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 13 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation adjustably rotated among or between some or all degrees between 1 and 90 and the grass guide of claim 2, wherein an internal combustion engine is used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 14 (canceled): A lawnmower using the rotary cutting apparatus of claim 1, with its plane of rotation fixed at a single degree between 1 and 90 and the grass guide of claim 2, wherein an internal combustion engine is used for driving the rotary cutting apparatus of claim 1. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide reduces the size of the blade's cutting area. Additionally, by bending the grass, the grass guide constrains the movement of the grass, thereby making it easier for the plurality of blades to cut the grass. Another advantage is the utilization of a plurality of small blades, which results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of blades from that of a conventional lawnmower blade.

Claim 15 (canceled): A lawnmower using the cutting apparatus of claim 1, wherein a string-like cutting member is substituted.

Claim 16 (canceled): A lawnmower using the cutting apparatus of claim 1, wherein a wire cutting member is substituted.

Claim 17 (canceled): A lawnmower using the cutting apparatus of claim 1, wherein the plurality of small blades are designed aerodynamically to have very little air resistance.

Claim 18 (new): A rotary cutting apparatus comprising

a plurality of blades, each blade fixed to the end of a drive shaft in substantially perpendicular orientation to the shaft, each shaft projecting downward from a power means at an angle tilted longitudinally between 1 and 90 degrees from vertical,
a grass guide,

a chassis to which said rotary cutting apparatus is affixed, and

a means for effecting movement of the apparatus over a cutting surface.

Claim 19 (new): The rotary cutting apparatus of claim 18, wherein said grass guide bends and constrains grass to be cut by the blades.

Claim 20 (new): The rotary cutting apparatus of claim 18, wherein said angle is adjustably selected from the group consisting of some or all degrees between 1 and 90 degrees from vertical.

Claim 21 (new): The rotary cutting apparatus of claim 18, wherein said angle is fixed at a single degree between 1 and 90 from vertical.

Claim 22 (new): The rotary cutting apparatus of claim 18, wherein said means for effecting movement of the apparatus over a cutting surface comprises

a handle to facilitate manual propulsion of the apparatus over the cutting surface and

a plurality of wheels.

Claim 23 (new): The rotary cutting apparatus of claim 18, wherein said power means comprises a single electric motor.

Claim 24 (new): The rotary cutting apparatus of claim 18, wherein said power means comprises a plurality of small electric motors.

Claim 25 (new): The rotary cutting apparatus of claim 18, wherein said power means consists of an internal combustion engine.

Claim 26 (new): The rotary cutting apparatus of claim 18, wherein said power means consists of a hybrid power source comprising

an internal combustion engine and

one or more electric motors.

Claim 27 (new): The rotary cutting apparatus of claim 23, wherein said motor or motors is powered by a battery or batteries.

Claim 28 (new): The rotary cutting apparatus of claim 24, wherein said motor or motors is powered by a battery or batteries.

Claim 29 (new): The rotary cutting apparatus of claim 23, wherein said motor or motors is powered by

a combination of a battery or batteries and
a solar cell.

Claim 30 (new): The rotary cutting apparatus of claim 24, wherein said motor or motors is powered by

a combination of a battery or batteries and
a solar cell.

Claim 31 (new): The rotary cutting apparatus of claim 23, wherein said motor or motors is powered by a fuel cell.

Claim 32 (new): The rotary cutting apparatus of claim 24, wherein said motor or motors is powered by a fuel cell.

Claim 33 (new): The rotary cutting apparatus of claim 18, wherein said cutting blades are replaceable.

Claim 34 (new): The rotary cutting apparatus of claim 18, wherein said power means is replaceable.

Claim 35 (new): The rotary cutting apparatus of claim 18, wherein said means for effecting movement of the apparatus over a cutting surface is robotic.

Claim 36 (new): The rotary cutting apparatus of Claim 18, wherein the height of said cutting blades relative to the cutting surface is adjustable.

Abstract of the Disclosure

A lawnmower consisting essentially of a novel rotary cutting apparatus comprising a plurality of small, lightweight blades and a grass guide for bending and constraining the grass for ease of cutting. The grass guide projects downward from the mower chassis and is positioned slightly forward of the blades. As the mower is propelled forward, the grass guide bends the grass forward and constrains movement of the grass such that only the outer radii of the blades contact the grass, optimizing cutting efficiency. The blades may be individually driven by one or more small electric motors powered by a rechargeable battery or batteries or other source. The drive shafts are situated at an angle adjustably tilted between 1 and 90 degrees in the longitudinal direction from vertical in order to limit the cutting area of the blades.

~~This invention discloses a rotary cutting apparatus and grass guide for mowing lawns. The rotary cutting apparatus consists of a plurality of small blades with their plane of rotation rotated between 1° and 90° from the horizontal plane of rotation. The rotation of the small blades from the horizontal plane of rotation working in conjunction with the grass guide results in a significant savings in required rotational kinetic energy due to the large reduction in mass of the plurality of small blades from that of a single large blade. The combination of this more efficient cutting design with the significant savings in required rotational kinetic energy allows for a smaller, quieter, lighter and less powerful motor or motors to be used. This results in a smaller, safer, quieter and lighter lawnmower, which is easier to operate and store.~~